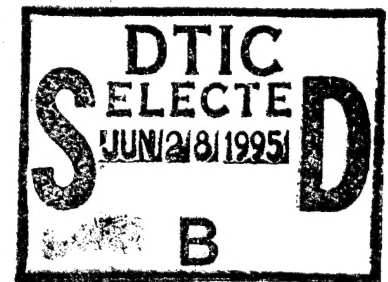TECHNICAL REPORT ARCCB-TR-95017

NEURAL NETWORKS IN SEIZURE DIAGNOSIS

M. A. JOHNSON
G. KENDALL
P. J. COTE
L. V. MEISEL

DTIC
SELECTED
JUN 28 1995
B

MARCH 1995

**US ARMY ARMAMENT RESEARCH,
DEVELOPMENT AND ENGINEERING CENTER**
CLOSE COMBAT ARMAMENTS CENTER
BENÉT LABORATORIES
WATERVLIET, N.Y. 12189-4050

U.S. ARMY ARDEC

BENÉT LABS

19950627 045

DTIC QUALITY INSPECTED 1

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1995	Final

4. TITLE AND SUBTITLE
NEURAL NETWORKS IN SEIZURE DIAGNOSIS

5. FUNDING NUMBERS
AMCMS No. 6111.02.H611.1
PRON No. 1A13Z1CANMBJ

6. AUTHOR(S)
M.A. Johnson, G. Kendall, P.J. Cote, and L.V. Meisel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army ARDEC
Benet Laboratories, AMSTA-AR-CCB-O
Watervliet, NY 12189-4050

8. PERFORMING ORGANIZATION REPORT NUMBER
ARCCB-TR-95017

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army ARDEC
Close Combat Armaments Center
Picatinny Arsenal, NJ 07806-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Presented at Artificial Neural Networks in Engineering (ANNIE '94), St. Louis, MO, 13-16 November 1994.
Published in Proceedings of ANNIE '94.

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

A monitor has been designed to detect the onset of *status epilepticus* associated with complex partial seizures in children. A unique sensor technology was developed to detect the minor, barely perceptible tremors characteristic of partial seizures. A microcontroller analyzes the sensor data and activates a remote tetherless alarm when a seizure is detected. However, the sensor response is similar for both casual and seizure activity, therefore, false alarms do occur. Neural networks have been studied as a means of analyzing the sensor response and differentiating seizure activity from casual motion. The network uses elements of the normalized power spectrum of the response data as a feature set. Our results indicate this approach provides a faster and more reliable means of accurately detecting seizures than the method currently employed.

14. SUBJECT TERMS
Epilepsy, Neural Networks, Seizures, Monitor, *Status Epilepticus*

15. NUMBER OF PAGES
11

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Accession For

NTIS GRA&I	☑	
DTIC TAB	☐	
Unannounced	☑	
Justification		

By_____
Distribution/

Availability Codes

Dist	Avail and/or Special
A-1	

i

ACKNOWLEDGEMENTS

EPILEPSY

Epilepsy is a disorder of the brain characterized by recurring seizures, in which there are uncontrolled electrical discharges of brain cells (ref 1). Epilepsy may arise from a very small area of damaged brain tissue, or from the entire brain. There may be no apparent brain damage, or damage limited to an area so small it cannot be detected. Therefore, in nearly one-half the cases, the cause of epilepsy is not known.

There are several types of seizures associated with epilepsy, the most common of which are generalized tonic-clonic (grand mal), absence (petit mal), complex partial (psychomotor), and elementary partial (focal motor). Each seizure type can be characterized by various symptoms. However, the seizures are generally not life-threatening, lasting at most up to three minutes. The exception is *status epilepticus,* also called continuous- seizure state. This is the occurrence of repetitive or continuous seizures and affects approximately 3 to 5 percent of those individuals suffering from epilepsy. It can exist with all types of seizures and may result in irreversible brain damage or death without prompt medical treatment.

THE PROBLEM

A tetherless monitor has been designed (ref 2) (Figure 1) for parents of children afflicted with epilepsy to supplement ineffectual periodic observation during sleeping hours. It was developed to detect the onset of *status epilepticus* associated with seizures that begin as complex partial and progress to generalized tonic-clonic. The early stages of these seizures are characterized by a loss of consciousness during which there are minor, barely perceptible tremors. The monitor sensor is capable of detecting the "hard shiver" activity characteristic of complex partial seizures. It is small and inexpensive to produce since it detects without measuring.

The sensor is an intermittent switch consisting of a small, electrically conductive sphere that is able to move within the confines of a small hollow cylinder with closed ends (Figure 2). The sphere is stainless steel and has been chemically treated (Marble's reagent) to enhance surface roughness. The wall of the cylinder is conductive as are the end plates, each of which is separated from the cylinder wall by an insulator. The end plates are electrically connected and form one pole of the switch. The cylinder wall is the other pole. When the sphere is in contact with either of the end plates and the cylinder wall, the switch is mechanically closed. However, depending on the presence of oxides and/or surface roughness, the contact resistance may be quite high and the switch may or may not be electrically closed. The important feature is that even small motions of the switch cause the ball to roll. The mechanically closed position (sphere in contact with the cylindrical surface B and one of the end caps A) is the only stable position of the sphere, so most rolling occurs in this position. As the sphere rolls, electrical contact with the wall is intermittent due to the

1

variations in contact resistance. The surfaces have been tapered to improve the probability of a weighted contact. No attempt has been made to optimize the taper or utilize curved surfaces since the design of Figure 2 has proved to be satisfactory.

Quasi-continuous activity for a finite period of time is used as an indication of seizure activity. In the current design, any sensor activity detected in a series of contiguous five-second windows satisfies the alarm criteria. This technique ensures consistent results at all monitor orientations and reduces the number of false alarms due to casual motion. However, false alarms inevitably still occur which cause undue anxiety for the caregivers.

A SOLUTION

In an effort to more reliably detect seizures, the sensor response data were recorded off-line for analysis. Data were sampled at 500 μsec, which is near the sampling rate of the microcontroller used in the monitor. While the technology required to collect data in real time is currently being developed, simulations of both casual motion (i.e., simulation of rolling over during sleep) and "hard shiver" activity (simulated by a very slight shivering motion) were generated in the laboratory. These simulations were performed by several different individuals based on descriptions of seizure activity provided by both physicians and caregivers of those afflicted with the disorder.

Figure 3 shows four seconds of sensor response typical of both types of motion. A Fourier analysis was performed on the data in an effort to identify a seizure by isolating conspicuous spectral components. Figure 4 shows samples of smoothed power spectral densities (PSD) for both types of motion. No peaks have been observed in the PSD of the sensor response. In fact, these figures appear to indicate no clear distinction between sensor response to shiver or to casual motion. Our analysis has shown that both spectrums have the form of flicker noise originating from hyperbolic distributions of noise pulse durations. This is one of the characteristics of self-organized critical behavior. Because of the absence of any obvious distinguishing peaks in the PSD, neural networks were employed as an alternative in an effort to identify subtle differences in the power spectrums.

Four seconds of 500 μsec data was used to compute the power spectrum. Approximately one hundred training sets were generated by contiguously shifting a four-second time window along four thirty-five second data sets. The power spectrum for each window was computed, normalized (between 0.2 and 0.8), and 51-point smoothing applied to the entire spectrum. The smoothed data were binned into 24 equally spaced segments and the center frequency components used as the feature vectors for a 24 x 10 x 1 feedforward network. Standard back propagation (ref 3) was used to modify the interconnects during training. The single output cell of the network was used to predict the presence or absence of seizure activity in the recorded response data.

2

The network converged to a solution after about 10K iterations with a learning rate of 0.03 and momentum term of 0.5. Performance of the network reached an asymptote at this point, by which time the summed squared error decreased to a value of 0.02. Figure 5 illustrates the performance of this network to response data not included in the training set. The neural network successfully classified all instances of seizure activity and casual motion for the training data and the test sets.

CONCLUSIONS

The smooth, flicker noise nature of the power spectral densities initially indicated there may not be enough information in the sensor response data to distinguish seizures from casual motion. It was thus surprising that the network converged to a solution during training and correctly identified seizures in the test sets. This clearly demonstrates the utility of neural networks. We plan to test different network configurations and use a smaller time window to further reduce the monitor response time.

The network has not been ported to the microcontroller used in the monitor electronics. It is simply not powerful enough to support the mathematics. However, there is now reason to believe a more complete analysis of sensor response can be devised to detect seizures while masking virtually all activity associated with casual motion. In addition, the time required to identify a seizure can be reduced by at least an order of magnitude. Since this promises dramatic improvements in monitor performance, a suitable redesign of the monitor electronics is currently in progress.

FUTURE WORK

The Center for the Disabled, Albany, NY, has requested Benet produce 20 additional units for patients with similar disorders. Furthermore, teachers at the Center have expressed an interest in monitoring a number of disabled children throughout the day. The latter is a challenge, however, the neural network results indicate the existing design could be modified for daytime monitoring. Pulse analysis techniques will be employed to analyze sensor response in an effort to determine the criteria the neural network uses for classifying the signals. We hope to discover a simple metric that the microcontroller can utilize to distinguish casual activity from seizures.

REFERENCES

1. H. Gestaut, Clinical and Electroencephalographical Classification of Epileptic Seizures, *Epilesia*, Chapter 11, 1970, pp. 102-113; and *EPILEPSY, Medical Aspects*, No. 022-1281-MSP, Epilepsy Foundation of America, 1979.

2. M.A. Johnson, and T.E. Simkins, "Monitor for *Status Epilepticus* Seizures." Proceedings of NASA Technology 2003, December 1993.

3. D.E. Rumelhart, J.L. McClelland, and the PDP Research Group, *Parallel Distributed Processing*, The MIT Press, Massachusetts, 1986.
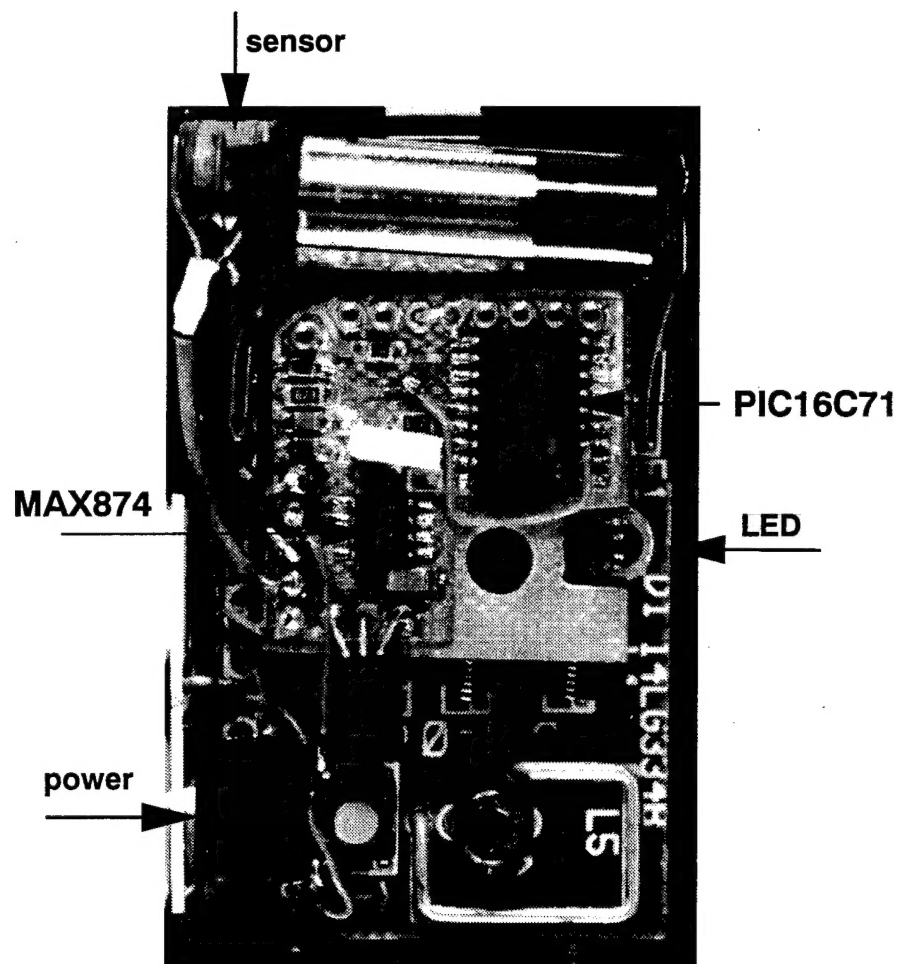
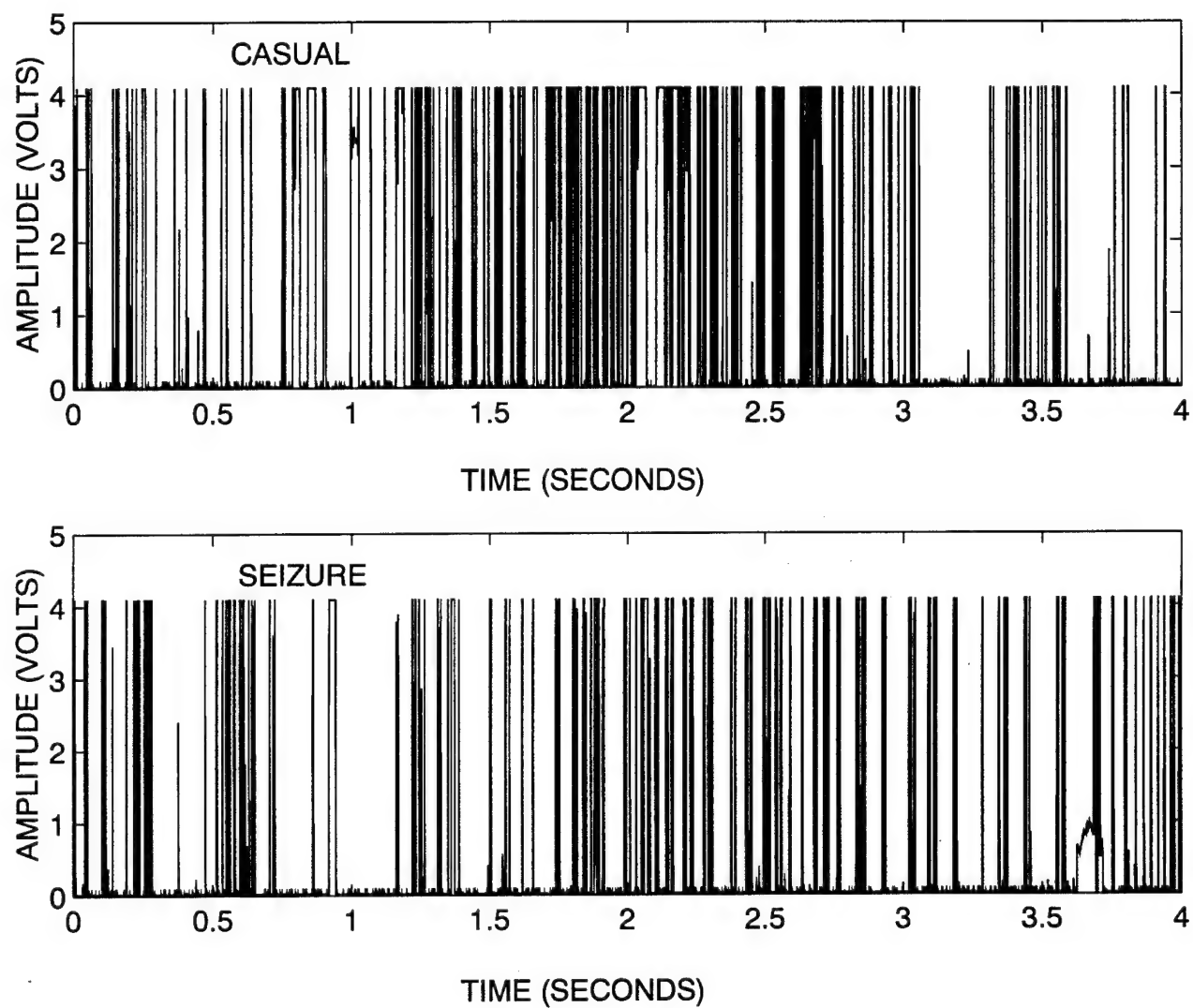Figure 1. Monitor hardware.

Figure 2. Sensor cross section.

6

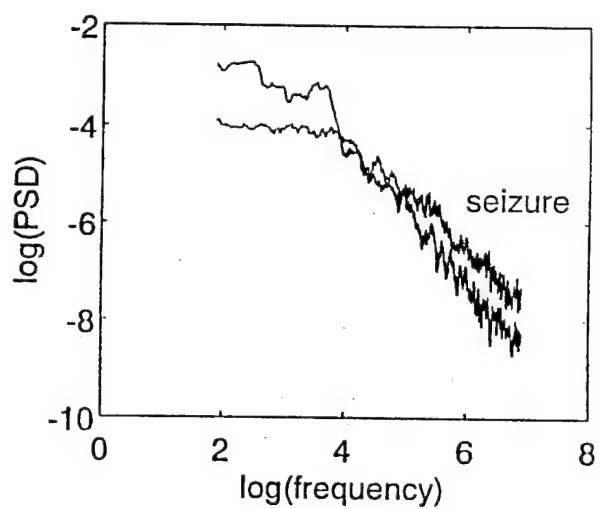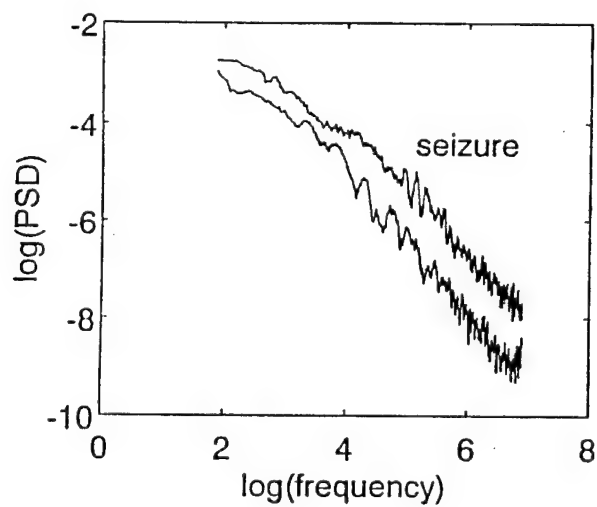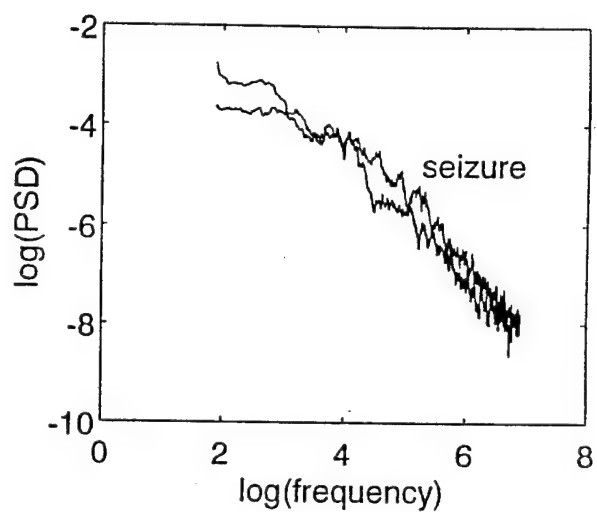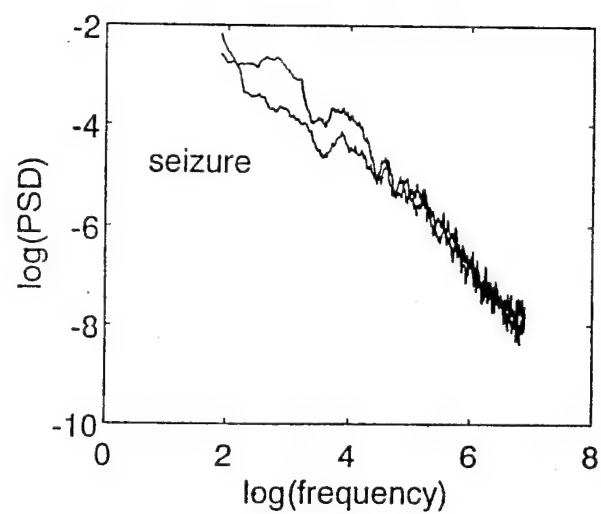Figure 3. Sensor response for seizure and casual motion.

Figure 4. Smoothed power spectral densities for seizure activity and casual motion for four different four-second intervals.

Figure 5. Output node response to 32 test sets.

TECHNICAL REPORT INTERNAL DISTRIBUTION LIST

	NO. OF COPIES
CHIEF, DEVELOPMENT ENGINEERING DIVISION	
ATTN: AMSTA-AR-CCB-DA	1
-DB	1
-DC	1
-DD	1
-DE	1
CHIEF, ENGINEERING DIVISION	
ATTN: AMSTA-AR-CCB-E	1
-EA	1
-EB	1
-EC	
CHIEF, TECHNOLOGY DIVISION	
ATTN: AMSTA-AR-CCB-T	2
-TA	1
-TB	1
-TC	1
TECHNICAL LIBRARY	
ATTN: AMSTA-AR-CCB-O	5
TECHNICAL PUBLICATIONS & EDITING SECTION	
ATTN: AMSTA-AR-CCB-O	3
OPERATIONS DIRECTORATE	
ATTN: SMCWV-ODP-P	1
DIRECTOR, PROCUREMENT & CONTRACTING DIRECTORATE	
ATTN: SMCWV-PP	1
DIRECTOR, PRODUCT ASSURANCE & TEST DIRECTORATE	
ATTN: SMCWV-QA	1

NOTE: PLEASE NOTIFY DIRECTOR, BENÉT LABORATORIES, ATTN: AMSTA-AR-CCB-O OF ADDRESS CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST

	NO. OF COPIES		NO. OF COPIES

ASST SEC OF THE ARMY
RESEARCH AND DEVELOPMENT
ATTN: DEPT FOR SCI AND TECH   1
THE PENTAGON
WASHINGTON, D.C. 20310-0103

ADMINISTRATOR
DEFENSE TECHNICAL INFO CENTER   2
ATTN: DTIC-OCP (ACQUISITION GROUP)
BLDG. 5, CAMERON STATION
ALEXANDRIA, VA 22304-6145

COMMANDER
U.S. ARMY ARDEC
ATTN: SMCAR-AEE   1
     SMCAR-AES, BLDG. 321   1
     SMCAR-AET-O, BLDG. 351N   1
     SMCAR-FSA   1
     SMCAR-FSM-E   1
     SMCAR-FSS-D, BLDG. 94   1
     SMCAR-IMI-I, (STINFO) BLDG. 59   2
PICATINNY ARSENAL, NJ 07806-5000

DIRECTOR
U.S. ARMY RESEARCH LABORATORY
ATTN: AMSRL-DD-T, BLDG. 305   1
ABERDEEN PROVING GROUND, MD
   21005-5066

DIRECTOR
U.S. ARMY RESEARCH LABORATORY
ATTN: AMSRL-WT-PD (DR. B. BURNS)   1
ABERDEEN PROVING GROUND, MD
   21005-5066

DIRECTOR
U.S. MATERIEL SYSTEMS ANALYSIS ACTV
ATTN: AMXSY-MP   1
ABERDEEN PROVING GROUND, MD
   21005-5071

COMMANDER
ROCK ISLAND ARSENAL
ATTN: SMCRI-ENM   1
ROCK ISLAND, IL 61299-5000

MIAC/CINDAS
PURDUE UNIVERSITY
P.O. BOX 2634   1
WEST LAFAYETTE, IN 47906

COMMANDER
U.S. ARMY TANK-AUTMV R&D COMMAND
ATTN: AMSTA-DDL (TECH LIBRARY)   1
WARREN, MI 48397-5000

COMMANDER
U.S. MILITARY ACADEMY
ATTN: DEPARTMENT OF MECHANICS   1
WEST POINT, NY 10966-1792

U.S. ARMY MISSILE COMMAND
REDSTONE SCIENTIFIC INFO CENTER   2
ATTN: DOCUMENTS SECTION, BLDG. 4484
REDSTONE ARSENAL, AL 35898-5241

COMMANDER
U.S. ARMY FOREIGN SCI & TECH CENTER
ATTN: DRXST-SD   1
220 7TH STREET, N.E.
CHARLOTTESVILLE, VA 22901

COMMANDER
U.S. ARMY LABCOM
MATERIALS TECHNOLOGY LABORATORY
ATTN: SLCMT-IML (TECH LIBRARY)   2
WATERTOWN, MA 02172-0001

COMMANDER
U.S. ARMY LABCOM, ISA
ATTN: SLCIS-IM-TL   1
2800 POWER MILL ROAD
ADELPHI, MD 20783-1145

NOTE: PLEASE NOTIFY COMMANDER, ARMAMENT RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER,
     BENÉT LABORATORIES, CCAC, U.S. ARMY TANK-AUTOMOTIVE AND ARMAMENTS COMMAND,
     AMSTA-AR-CCB-O, WATERVLIET, NY 12189-4050 OF ADDRESS CHANGES.

	NO. OF COPIES		NO. OF COPIES
COMMANDER U.S. ARMY RESEARCH OFFICE ATTN: CHIEF, IPO P.O. BOX 12211 RESEARCH TRIANGLE PARK, NC 27709-2211	1	WRIGHT LABORATORY ARMAMENT DIRECTORATE ATTN: WL/MNM EGLIN AFB, FL 32542-6810	1
DIRECTOR U.S. NAVAL RESEARCH LABORATORY ATTN: MATERIALS SCI & TECH DIV CODE 26-27 (DOC LIBRARY) WASHINGTON, D.C. 20375	1 1	WRIGHT LABORATORY ARMAMENT DIRECTORATE ATTN: WL/MNMF EGLIN AFB, FL 32542-6810	1

NOTE: PLEASE NOTIFY COMMANDER, ARMAMENT RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER, BENÉT LABORATORIES, CCAC, U.S. ARMY TANK-AUTOMOTIVE AND ARMAMENTS COMMAND, AMSTA-AR-CCB-O, WATERVLIET, NY 12189-4050 OF ADDRESS CHANGES.